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Study on Ecological Environmental Impact Assessment of Saihanba Afforestation Project Based on Grey Target Model

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Abstract: With the help of the Chinese government, China's Saihanba Forest Farm has recovered from the desert and has now become an eco-friendly green farm with stable sand control function. After more than half a century of struggle, the largest artificial forest in the world was built in Saihanba. We expanded the afforestation of 1.12 million mu and planted more than 400 million trees. The builders created a green ocean on the plateau wasteland 400 kilometers north of Beijing. Therefore, through the data collection and analysis of Saihanba, this paper establishes the ecological environment impact assessment model of Saihanba based on the gray target model. According to the evaluation index and bull's eye value, using the data of plant abundance, plant coverage and total number of animals from 1966 to 2021, the environmental impact before and after the restoration of Saihanba is quantitatively analyzed by using the comprehensive index method.

1. Introduction

Economic and social development is moving towards a beautiful country with all-round green growth. Since 1962, 369 young people with an average age of less than 24 have come to Saihanba. Since then, they have dedicated their lives here, moving forward wave after wave, planting seeds in the sand, planting green in the cracks in the stone, and like nails, millions of acres of forest on the wasteland. They built a green barrier to prevent sandstorms. Today, the Saihanba area has reached 80%. It supplies 137 million cubic meters of clean water to Beijing and Tianjin every year, sequesters 747000 tons of carbon, and releases 545000 tons of oxygen. After more than half a century of struggle, the largest artificial forest in the world was built in Saihan Dam. We expanded the afforestation of 1.12 million mu and planted more than 400 million trees. The builders created a green ocean on the plateau wasteland 400 kilometers north of Beijing [0]. Therefore, the data obtained in this paper can be used to evaluate the afforestation project of Saihan Dam, identify the impact on the ecological environment and the degree of impact, help to achieve the coordinated development of the project, society and environment, and provide information for stakeholders and decision-makers.

In order to enhance the objectivity of index weighting and the comparability between different evaluation units, according to the degree and characteristics of the ecological environment impact of

Saihanba Afforestation Project, the entropy weight theory is introduced to weight the index, and the grey target model is selected to evaluate its ecological environment impact. In the absence of standard values, the target can be set according to the original data of the index, making the evaluation results more objective and reasonable [0]. Finally, the comprehensive index method is selected for comparative verification, the feasibility of the evaluation model is discussed, a new attempt is made to the ecological environment impact assessment method, and on the basis of the above, targeted ecological protection and restoration measures are proposed.

2. Model Building Process

2.1 Evaluation of Gray Target Mode

2.1.1 Constructing a Standard State Evaluation Matrix

Assuming that there are m units to be evaluated in this question, and each unit has n evaluation indicators, the first step is to construct the original judgment matrix:

$$A = \left(a_{ij}\right)_{m\times n} \tag{1}$$

In the formula: a_{ij} represents the corresponding value of the j evaluation index in the evaluation unit i.

Evaluation indicators are divided into positive indicators and negative indicators. Positive indicators have the attribute of maximum value, while negative indicators have the attribute of minimum value, so they need to be dealt with separately:

Positive indicators will be processed according to the following formula:

$$r_{\mathrm{ij}} = \frac{a_{\mathrm{ij}} - \min\limits_{1\le i\le m} \mathrm{a_{ij}}}{\max\limits_{1\le i\le m} \mathrm{a_{ij}} - \min\limits_{1\le i\le m} \mathrm{a_{ij}}} \tag{2}$$

Negative indicators will be processed according to the following formula:

$$r_{\mathrm{ij}} = \frac{\max\limits_{1\le i\le m} \mathrm{a_{ij}} - a_{\mathrm{ij}}}{\max\limits_{1\le i\le m} \mathrm{a_{ij}} - \mathrm{min}\,\mathrm{a_{ij}}} \tag{3}$$

Get the standard state evaluation matrix:

$$R = (r_{\mathrm{ij}})_{m\times n} \tag{4}$$

In the formula: r_{ij} is the data after a_{ij} is standardized, $r_{ij} \in [0,1]$.

2.1.2 Determine the Index Weight

The entropy method is based on the original data of the index to obtain the weight, which can reflect the importance of the evaluation index in a more objective and true manner[0]. The calculation process is as follows:

Entropy calculation of various evaluation indicators

Index value r_{ij} proportion:

$$P_{\mathrm{ij}} = \frac{r_{\mathrm{ij}}}{\sum_{i=1}^{m} r_{\mathrm{ij}}} \tag{5}$$

Because the entropy method needs to perform logarithmic operation on the value of Pij when calculating the weight of the index, so Pij needs to be greater than 0, so the above formula needs to be transformed:

$$f_{\mathrm{ij}} = \frac{1 + r_{\mathrm{ij}}}{\sum_{i=1}^{m}(1 + r)} \tag{6}$$

Then the entropy of index j is:

$$e_{ij} = -k \sum_{i=1}^{m} f_{ij} \bullet \mathrm{Lnf}_{ij} \tag{7}$$

In the formula: $k = 1 / Lnm$.

Calculation of entropy weight wj of the jth index

$$\omega_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \tag{8}$$

2.1.3 Constructing a Standardized Model

The standardization mode is a sequence composed of the standard status data of the evaluation index, which can most truly reflect the pros and cons of the evaluation unit. The standardization mode and various evaluation units form a gray target model. The formula for building a standardized model is as follows:

$$x_0 = \{x_0(U_1), x_0(U_2), x_0(U_3), \cdots, x_0(U_n)\} \tag{9}$$

In the formula: X0 is the sequence in the standard mode; Un is the nth non-standardized evaluative index; X0(Un) is the standardized evaluative index of Un, when Un is used as a positive index, X_0(Un) is used as the original data Maximum value, otherwise the minimum value.

2.1.4 Determine the Difference of Gray Correlation Information and Gray Target Transformation

After the standard state model and indicator system information are established, it is necessary to perform a measurement transformation for the sequence of each indicator, that is, to replace the T of the gray target, and then determine the information of the gray correlation difference space. The bullseye of this model is as follows:

$$x_0 = TX_0 = (\underbrace{1,1,1,\cdots,1,1,1}_{M}) \tag{10}$$

In the formula: x_0 is the bullseye; m is the number of evaluation units; the gray target transformation formula is as follows:

$$x_i(U_k) = TX_i(U_k) = \frac{min\{X_i(U_k), X_0(U_k)\}}{max\{X_i(U_k), X_0(U_k)\}} \tag{11}$$

In the formula: $x_i(U_k)$ is expressed as the value of U_k after gray target transformation, Xi(Uk) is expressed as the original value of U_k, and $X_o(U_k)$ is expressed as the standard value of evaluation index U_k.

The information of the gray correlation difference space is a matrix composed of the standardized values of various indicators and the values after gray target transformation. The relevant calculation formula is as follows:

$$\Delta = \{\Delta_{0i}(U_K)\} = |x_0(U_K) - x_i(U_K)| \tag{12}$$

In the formula, Δ represents the difference information collection library, and the value of xo (U_k) is 1, so the above formula can be equivalently expressed as:

$$\Delta = \{\Delta_{0i}(U_K)\} = |1 - X_i(U_K)| \tag{13}$$

2.1.5 Calculate Bullseye Degree and Bullseye Coefficient

The method of calculating bullseye coefficient is as follows:

$$\gamma[x_0(U_K), x_i(U_K)] = \frac{\min_i \min_k \Delta_{0i}(U_K) + 0.5 \max_i \max_k \Delta_{0i}(U_K)}{\Delta_{0i}(U_K) + 0.5 \max_i \max_k \Delta_{0i}(U_K)} \tag{14}$$

In the formula: γ [x_o(U_k), x_i(U_k)] is the gray correlation between the evaluation index U_k of the evaluation unit X_i and the index corresponding to the standard state mode Xo, and $\Delta 0_i$(U_k) is the gray correlation of the evaluation index U_k of the evaluation unit Xi Differences in information.

The calculation of the bullseye degree is as follows:

$$\gamma(x_0, x_i) = \sum_{k=1}^{n} w_k\, \gamma[x_0(U_K), X_i(U_K)] \tag{15}$$

In the formula: $\gamma(x_o,x_i)$ represents the bullseye of the evaluation unit X_i, W_k index weight, $\gamma[x_o(U_k), x_i(U_k)]$ represents the evaluation index U_k of the evaluation unit X_i and the corresponding index in the standard mode X_o Bullseye coefficient.

2.2 Comprehensive Index Evaluation Method

According to the above formulas (2) and (3), the set indicators are standardized, and the ecological environment quality comprehensive index is calculated according to the following formula:

$$EI = \sum_{j=1}^{n} \omega_k \times r_{\mathrm{ij}} \tag{16}$$

In the formula: EI is the comprehensive evaluation index value of ecological environment quality; w_k is the weight value of the kth set index; r_{ij} is the standardized value of the jth index in the evaluation unit i; n is the number of evaluation indexes.

3. Case Analysis

3.1 Regional Division

Divide Saihanba into 5 areas, labeled as Area A, Area B, Area C, Area D, and Area E. The specific divisions are shown in the figure 1:

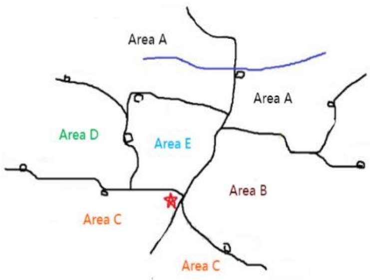

Figure 1 Saihanba Area Segmentation

3.2 Data Analysis

This paper randomly selects 20 years of data from the forest coverage rate, coverage area, and forest accumulation of Saihanba in the past 60 years (1962-2021) as the sample size for data analysis, Use Excel to analyze the forest coverage rate with a line graph, and the data and graphs are Table 1^0.

Table 1 Randomly Selected Data of Saihanba in Recent Years

Particular year	Forest coverage	Coverage area / 10000 mu	Forest volume / 10000 m^3	Water conservation volume / 100 million m^3	Carbon dioxide absorption / 10000 tons	Oxygen release / 10000 tons
1963	15.94	22.32	33.23	0.09	2.76	1.92
1966	22.70	31.77	36.55	0.10	3.03	2.11
1968	26.90	37.66	40.92	0.11	3.40	2.36
1975	39.76	55.67	68.92	0.18	5.72	3.98
1976	41.37	57.92	74.45	0.19	6.18	4.30
1980	47.25	66.15	100.15	0.24	8.31	5.78
1985	53.13	74.38	159.08	0.30	13.20	9.18
1989	57.00	79.80	248.50	0.36	20.62	14.34
1990	58.08	81.31	254.50	0.37	21.12	14.69
1994	62.94	88.11	344.17	0.44	28.56	19.86
1997	66.53	93.15	428.56	0.51	35.56	24.73
2001	70.16	98.23	615.18	0.61	51.05	35.51
2002	70.71	99.00	683.60	0.64	56.72	39.45
2005	71.74	100.44	788.14	0.75	65.40	45.49
2006	71.98	100.77	815.64	0.79	67.68	47.08
2008	72.43	101.40	862.36	0.87	71.56	49.77
2013	74.50	104.30	951.22	1.12	78.93	54.90
2016	77.89	109.05	990.18	1.30	82.16	57.15
2019	80.66	112.93	1020.7	1.94	84.69	58.91
2021	82.21	115.10	1036.80	2.84	86.03	59.84

In this paper, among the forest coverage rate, coverage area, forest volume and other data of Saihanba in recent 60 years (1962-2021), the data of 20 years are randomly selected as the sample size for data analysis, and the forest coverage rate is analyzed by using Origin. The line chart is shown in Figure 2:

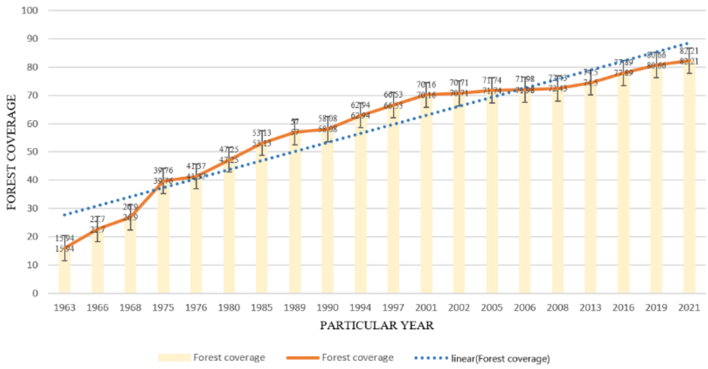

Figure 2 Forest Coverage Rate of Saihanba in Recent Years

According to figure 2, the forest coverage of Saihanba is increasing year by year in recent 60 years, and the growth rate of forest coverage is higher than the average growth rate from 1963 to 2005[0]. The analysis of forest coverage, carbon dioxide absorption and oxygen release data of Saihanba is shown in Figure 3:

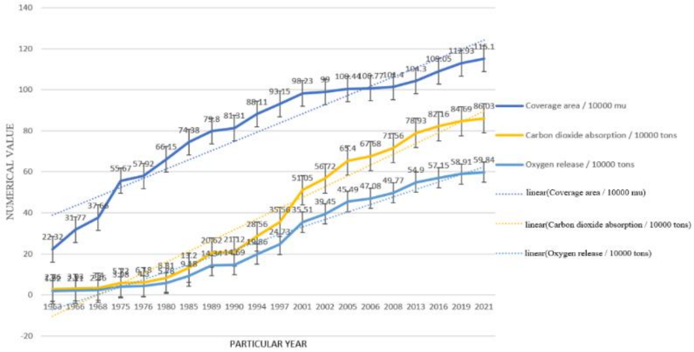

Figure 3 Coverage Area, Carbon Dioxide Absorption and Oxygen Release of Saihanba in Recent Years

Set the selected three-year time period as the frequency, and the selected data is Table 2:

Table 2 Grouped Data of Saihanba in Recent Years

Group	Forest coverage	Coverage area / 10000 mu	Forest volume / 10000 m^3	Water conservation volume/100 million m^3	Carbon dioxide absorption / 10000 tons	Oxygen release / 10000 tons	Forest coverage
I	1966	22.70	31.77	36.55	0.10	3.03	2.11
	1967	24.83	34.76	38.53	0.11	3.20	2.22
	1968	26.90	37.66	40.92	0.11	3.40	2.36
	1969	28.91	40.47	43.73	0.12	3.63	2.52
	1970	30.86	43.21	46.94	0.13	3.90	2.71
II	1991	59.24	82.93	274.40	0.39	22.77	15.84
	1992	60.44	84.62	297.08	0.40	24.65	17.15
	1993	61.69	86.36	320.13	0.42	26.56	18.48
	1994	62.94	88.11	344.17	0.44	28.56	19.86
	1995	64.18	89.85	369.84	0.46	30.69	21.35
III	2017	78.93	110.50	1001.10	1.37	83.07	57.78
	2018	79.82	111.74	1011.29	1.56	83.91	58.37
	2019	80.66	112.93	1020.70	1.94	84.69	58.91
	2020	81.46	114.05	1029.23	2.40	85.40	59.40
	2021	82.21	115.10	1036.80	2.84	86.03	59.84

According to the analysis of the data, the data pattern of the above three-year time period is consistent with the trend of the above random data.

It is required to establish an evaluation model of Saihanba's impact on the ecological environment, and select three time periods on this basis. First, select the evaluation indicators from the three perspectives of the pressure system, the state subsystem, and the response subsystem, and then calculate the weight of each indicator according to the PSR evaluation indicator system to reflect its importance, and finally use the gray target model to calculate the three-year time period Comprehensive evaluation value, and then compare the three sets of values, and then get the impact of Saihanba on the ecological environment before and after the reconstruction.

3.3 Model Solution

3.3.1 The Value of the Index Factor

The impact of vegetation coverage on the ecological environment of Saihanba includes natural, social, ecological and other factors. Constructing a reasonable ecological environment evaluation index system is the prerequisite for reasonable evaluation. In the answer to this question, based on

PSR-grey target The model, combined with the vegetation coverage area of Saihanba in previous years, considers the tourist growth rate, biodiversity, domestic sewage treatment rate and other index factors under the pressure subsystem, status subsystem, and response subsystem to solve the model. Specific indicators The value of the factor is shown in Table 3:

Table 3 Values of the Index Factors of Saihanba

Target layer	Factor layer	Subsystem layer	Reference weight
Evaluation of Saihan dam's impact on ecological environment	Vegetation impact	D1 Plant abundance	
		D2 Total number of plants	0.0108
		D3 Plant coverage area	0.0234
	Animal impact	D4 Animal abundance	0.0315
		D5 Total number of animals	0.279
		D6 Animal activity area	0.163
	Climate impact	D7 Rainfall	0.247
		D8 Wind force	0.174
		D9 Thunder weather	0.038

3.3.2 Bullseye Calculation

After the standard state model and indicator system information are established, it is necessary to perform a measurement transformation for the sequence of each indicator, that is, to replace the T of the gray target, and then determine the information of the gray correlation difference space. The bullseye of this model is Table 4:

Table 4 Gray Target Model Bullseye

Evaluation area	Area A	Area B	Area C	Area D	Area E
C_1(-)	0.7844	1.0000	0.6009	0.4657	0.4119
C_2(-)	0.6872	0.4155	0.5060	1.0000	0.6111
C_3(-)	1.0000	0.3567	0.3528	0.3545	0.3442
C_4(-)	1.0000	0.4396	0.3515	0.4272	0.3430
C_5(-)	1.0000	0.3421	0.3494	0.3413	0.3533
C_6(-)	1.0000	0.4082	0.3790	0.3555	0.3555
C_7(+)	0.7009	0.7678	1.0000	0.7049	0.5742
C_8(+)	0.3662	1.0000	0.3549	0.3457	0.3423
C_9(+)	0.6338	1.0000	0.5625	0.8491	0.5202
C_{10}(+)	1.0000	0.6129	0.9048	0.9314	0.7364
C_{11}(+)	1.0000	0.5417	0.6594	0.9381	0.5260
C_{12}(-)	1.0000	0.7881	1.0000	0.9563	0.9279
C_{13}(-)	0.3333	1.0000	0.3333	0.3333	0.3333
C_{14}(-)	0.6006	0.8197	0.6473	1.0000	1.0000
C_{15}(+)	0.9256	0.9600	0.9569	1.0000	0.9029
C_{16}(+)	1.0000	0.8802	0.8269	0.8200	0.8481
C_{17}(+)	0.8683	0.9993	1.0000	0.8470	0.9716
C_{18}(+)	0.4118	1.0000	0.4074	0.6937	0.6364

3.3.3 Ecological Environment Quality Classification Standard

Table 5 Classification Criteria

Level	Very Good	Good	Generality	Relatively Poor	Poor
Bull's-eye value	$\gamma \geq 0.91$	$0.81 \leq \gamma \leq 0.91$	$0.71 \leq \gamma \leq 0.81$	$0.61 \leq \gamma \leq 0.71$	$\gamma \leq 0.61$
Composite index value	$EI \geq 0.8$	$0.6 \leq EI \leq 0.8$	$0.4 \leq EI \leq 0.6$	$0.2 \leq EI \leq 0.4$	$EI \leq 0.2$

The value range of γ is mainly concentrated in 0.41~0.91, and it is classified according to the principle of equal division and rounding. Finally, the ecological environment quality of the evaluation unit is divided into 5 grades, and the classification standards are shown in Table 5.

3.3.4 Actual Results

Use the above-mentioned PSR-grey target comprehensive evaluation model to calculate the environmental condition data of Saihanba before and after the restoration in 1966-1970, 1991-1995, and 2017-2021, obtain the comprehensive evaluation score for this time period, and then perform the calculation. The index comparison scheme is shown in Figure 4 and Table 6:

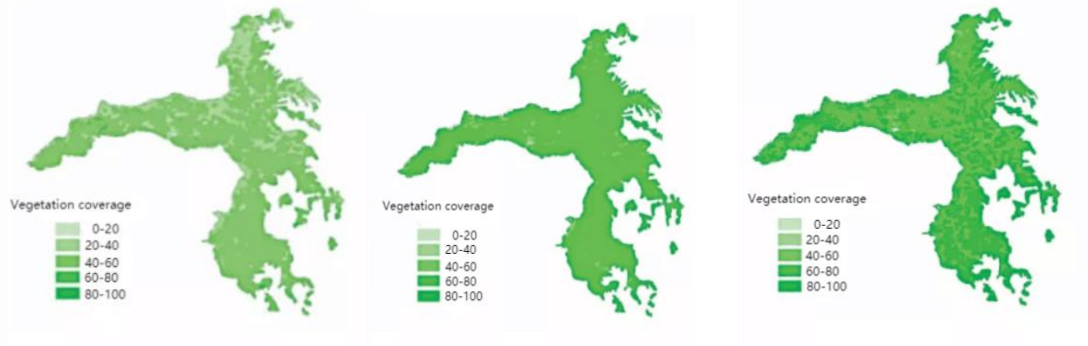

Figure 4 The Forest Coverage Rate in Three Periods of Saihanba

Table 6 Comparison of Various Indicators

Year segment	Composite index value	Grey target model evaluation results		Evaluation results of comprehensive index method	
		$\gamma(A)$	Grade	EI	Grade
1966-1970	Zone A	0.6790	Relatively Poor	0.5403	Poor
	Zone B	0.6610	Relatively Poor	0.6189	Relatively Poor
	Zone C	0.6161	Relatively Poor	0.5146	Poor
	Zone D	0.7188	Generality	0.5245	Poor
	Zone E	0.6001	Relatively Poor	0.3213	Relatively Poor
1991-1995	Zone A	0.7790	Generality	0.8403	Good
	Zone B	0.7610	Generality	0.8189	Good
	Zone C	0.7161	Generality	0.8846	Generality
	Zone D	0.7888	Generality	0.8745	Generality
	Zone E	0.7001	Generality	0.8213	Good
2017-2021	Zone A	0.8790	Good	0.8903	Good
	Zone B	0.8610	Good	0.9189	Very Good
	Zone C	0.8161	Very Good	0.8646	Good
	Zone D	0.7888	Generality	0.7945	Generality
	Zone E	0.8001	Very Good	0.7213	Generality

4. Conclusion

According to the above analysis, the environmental conditions before and after the restoration of Saihan Dam are quite different, which proves that the afforestation of Saihan Dam has greatly improved the local environment and increased the landscape diversity and water and soil in the region. Good results will be achieved by maintaining the capacity, strengthening the connectivity of the original habitat, and actively managing the water and soil loss and solid waste that have occurred by increasing environmental protection investment.

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